Warfighter Auditory Situation Awareness: Locating the Shooter with and without Hearing Protection

John G. Casali, Ph.D., CPE
jcasali@vt.edu
Virginia Tech
Kristen Talcott, Ph.D.
kristen.talcott@gmail.com
NAVAIR
John P. Keady, Ph.D., J.D.
drjpk22@hotmail.com
Innovation R&D Lab
Mead Killion, Ph.D., Sc.D. (hon)
m_killion@etymotic.com
Etymotic Research, Inc.

Human Systems Integration Symposium
October 25-27, 2011 Vienna, VA

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
OCT 2011		**00-00-2011 to 00-00-2011**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Warfighter Auditory Situation Awareness: Locating the Shooter with and without Hearing Protection	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Virginia Tech,Auditory Systems Lab,Blacksburg,VA,24061-0002**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**36**	

Acknowledgement & Disclaimer

- Funding and impetus provided by *Etymotic Research, Inc.* after the DARPA "B-E-E-P" workshop in January, 2010.

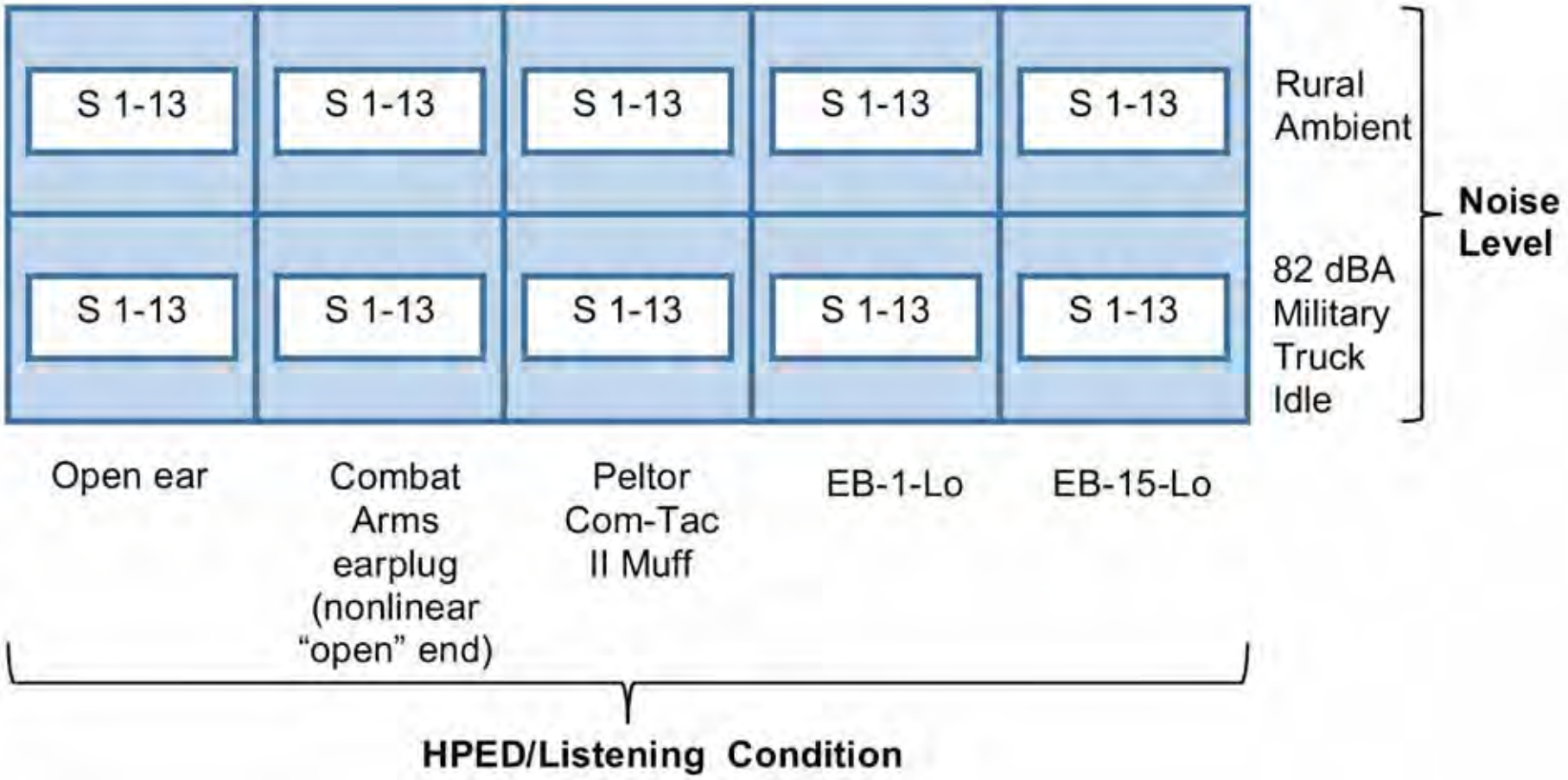
- Casali and Keady independently designed and conducted the experimental protocols. Talcott served as experimenter.

- Selection of HPEDs occurred after a review of the commercially-available technology at the time, and of devices currently in widespread use by the U.S. Army.

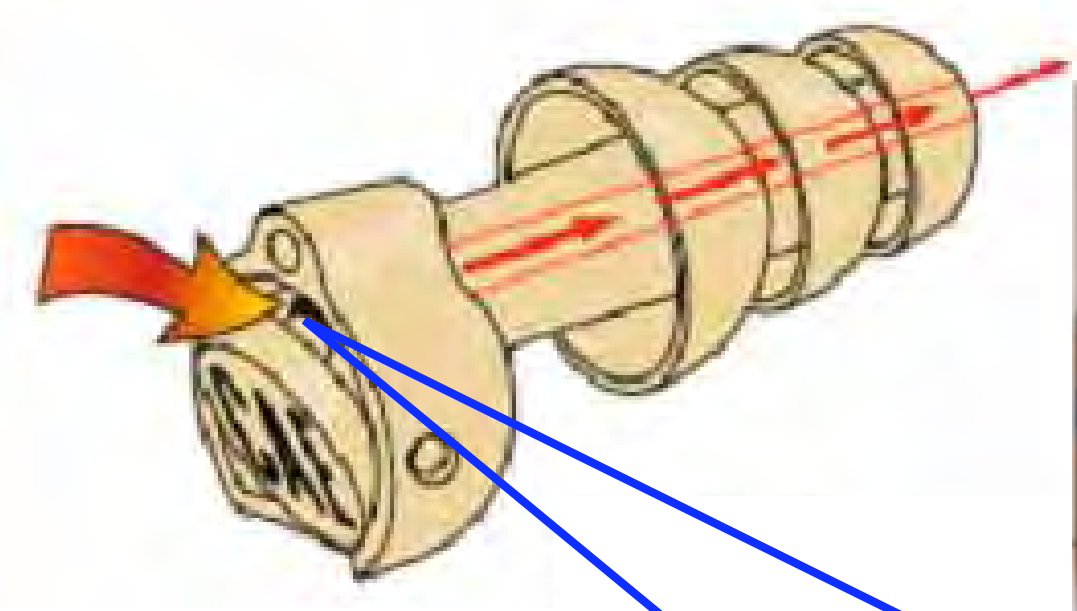
Warfighters Require Hearing Protection

- NIHL is the most common military disability (Saunders & Griest, 2009).
  - Over $1.2 billion spent on hearing injuries in 2006.
  - 2007: VA dispensed ~ 350,000 hearing aids at ~ $141 million.
- ~ 1/3 of soldiers from Iraq and Afghan theaters have NIHL (Ahroon, 2007).
- The hearing-impaired warfighter may pose a liability to himself and others in combat operations. "Survivability & Lethality" implications.
- Soldiers and pilots who lose their fitness-for-duty due to HL represent a huge $ investment lost.
- Vause & Grantham (1999) showed more errors in localizing a rifle being cocked with certain earplugs, compared to open ear.
- Warfighters have little confidence in, and won't use HPDs that compromise their situational awareness. (Casali et al, 2009)

“Controlled” Field Study: Experimental Design



Combat Arms™ Earplug: Rocker Switch Version
(AEARO/3M)



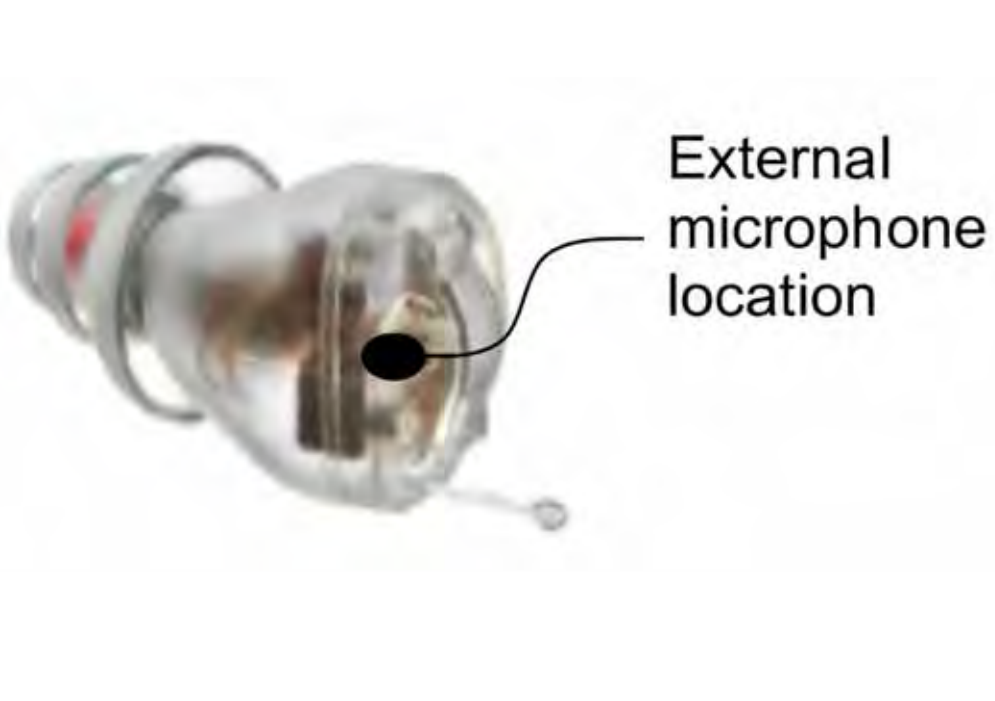
OPEN POSITION

Octave Band Attenuation Data (dB) All data per ANSI S3.19-1974										
Hz	125	250	500	1000	2000	3150	4000	6300	8000	NRR
Mean, dB	4.1	4.5	11.0	18.7	24.9	29.8	25.8	18.7	26.5	7
S.D., dB	2.7	2.8	3.9	3.2	3.3	2.7	3.3	3.6	3.3	

Peltor Com-Tac II™ Sound Transmission Earmuff (AEARO/3M)

		Octave Band Attenuation Data (dB) All data per S3.19-1974									
NRR*	CSA Class**		125	250	500	1000	2000	3150	4000	6300	8000
21	B	Mean	14.5	17.7	26.3	31.3	29.8	36.7	35.1	37.5	35.4
		SD	3.0	2.9	2.8	2.6	3.2	2.7	2.5	2.8	3.0

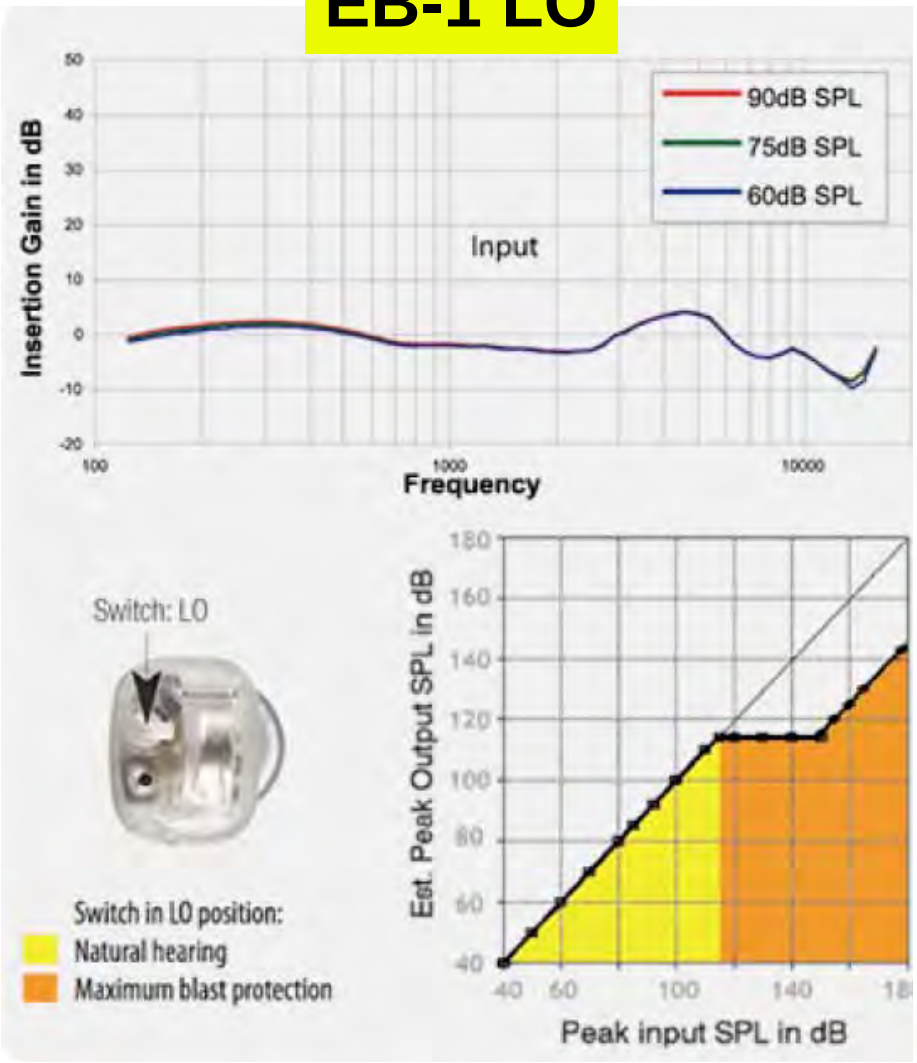
BlastPLGs™: EB-1 & EB-15 (identical appearance)
(Etymotic Research, Inc.)



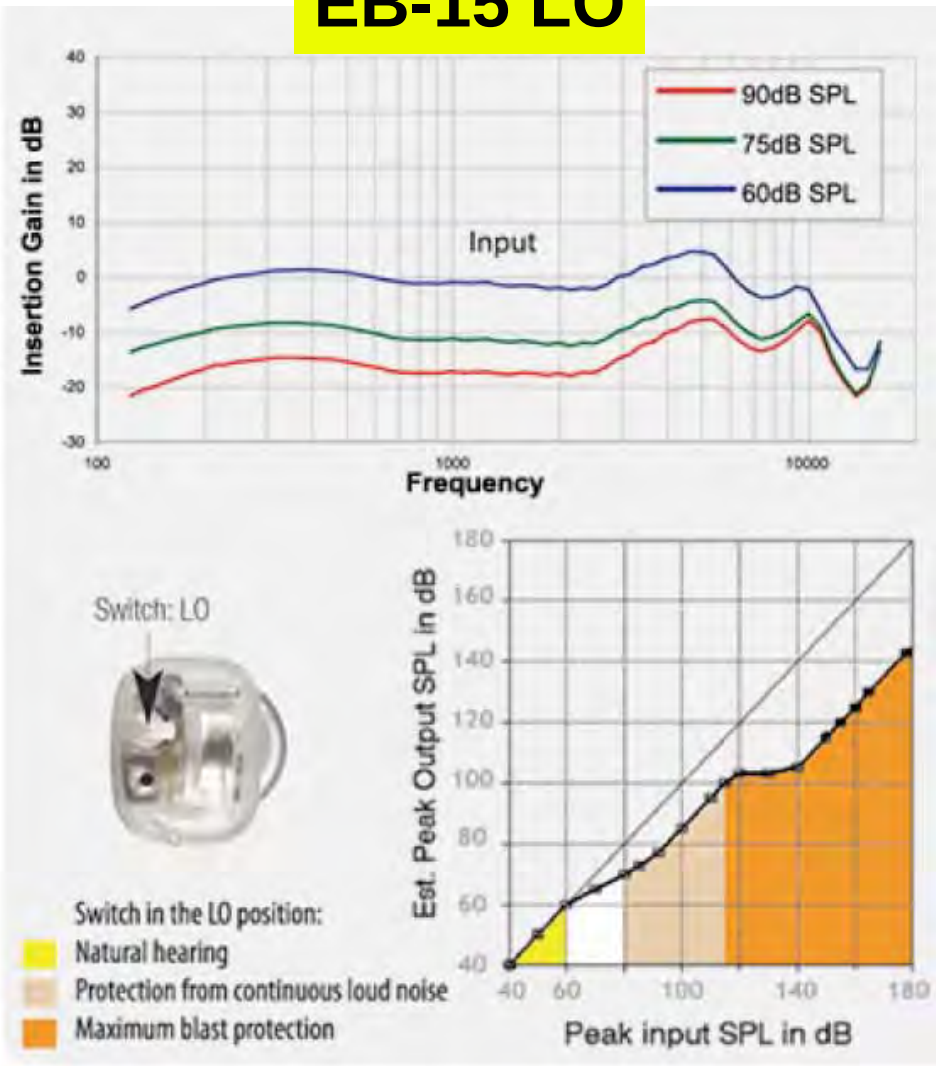
Attenuation Data per ANSI S3.19-1974									
NRR = 25	125	250	500	1000	2000	3150	4000	6300	8000
mean (dB)	28.1	29.3	32.9	34.3	37.9	41.3	40.4	39.3	40.6
s.d (dB)	3.7	3.6	4.7	5.7	2.6	3.9	5.4	4.6	4.9

BlastPLGs™: EB-1 & EB-15 Gain Profiles -- LO Position
(Etymotic Research, Inc.)

EB-1 LO



EB-15 LO



Subjects and Sessions

- Age: 22 - 54 years, $\bar{x}$ = 35; 10 male, 3 female

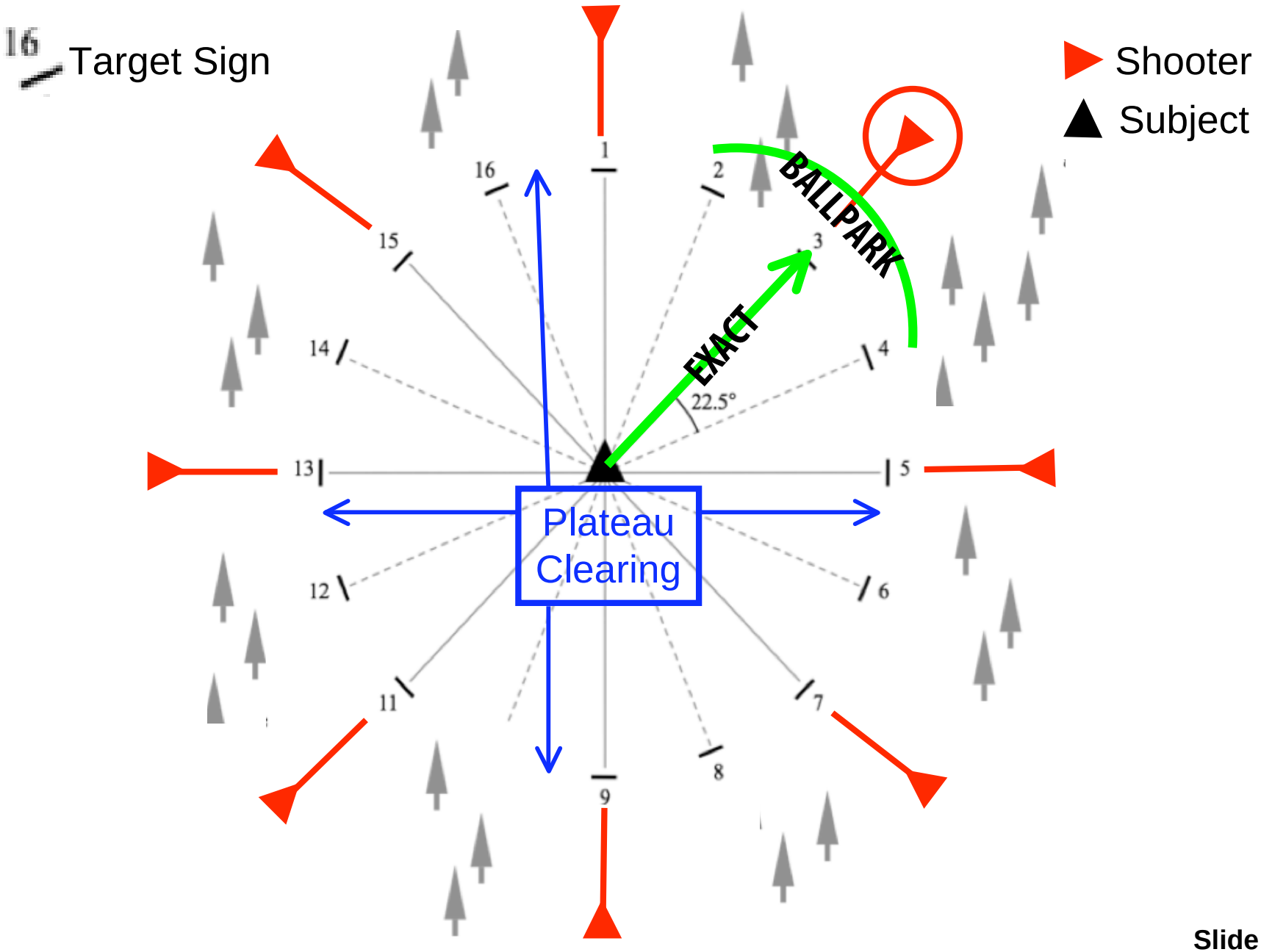
- (9) Normal hearing:
  - Each ear: ≤ 25 dBHL at 250 Hz to 6000 Hz
  - Symmetry: ≤ 15 dBHL difference between ears
- (4) Impaired hearing:
  - ≤ 25 dBHL at 250 Hz to 1000 Hz
  - ranged from 45 - 95 dBHL at 2000 Hz and above

- Attended 2 sessions:
  - Screening: otoscopy, PT audiogram, informed consent
  - Experimental (3 - 5 hrs)

Stepwise Protocol - Experimental Session

1) Subject (S) fit by Experimenter (E) with HPED; S faces flag target #1, E stands behind.
2) Truck Noise on or off (with generator as appropriate).
3) E initiates 75 dBA pink noise to mask Shooters' movements in woods. E radios 3 Shooters to move to positions. Shooters confirm upon arrival.
4) E turns pink noise off. S removes black goggles.
5) Digital recorder ON. Designated shooter fires gun - stopwatch ON.
6) S verbalizes target sign #, as QUICKLY and ACCURATELY as possible. Stopwatch OFF.
7) Repeat of steps 2 - 6 for all 8 Shooter positions x 2 trials each.
8) S performs ratings of HPED/OE condition.
9) Return to step 1 for next HPED/OE condition, randomized.

Field Test Site Configuration: *Measures*



Instrumented Subject at Center of Plateau

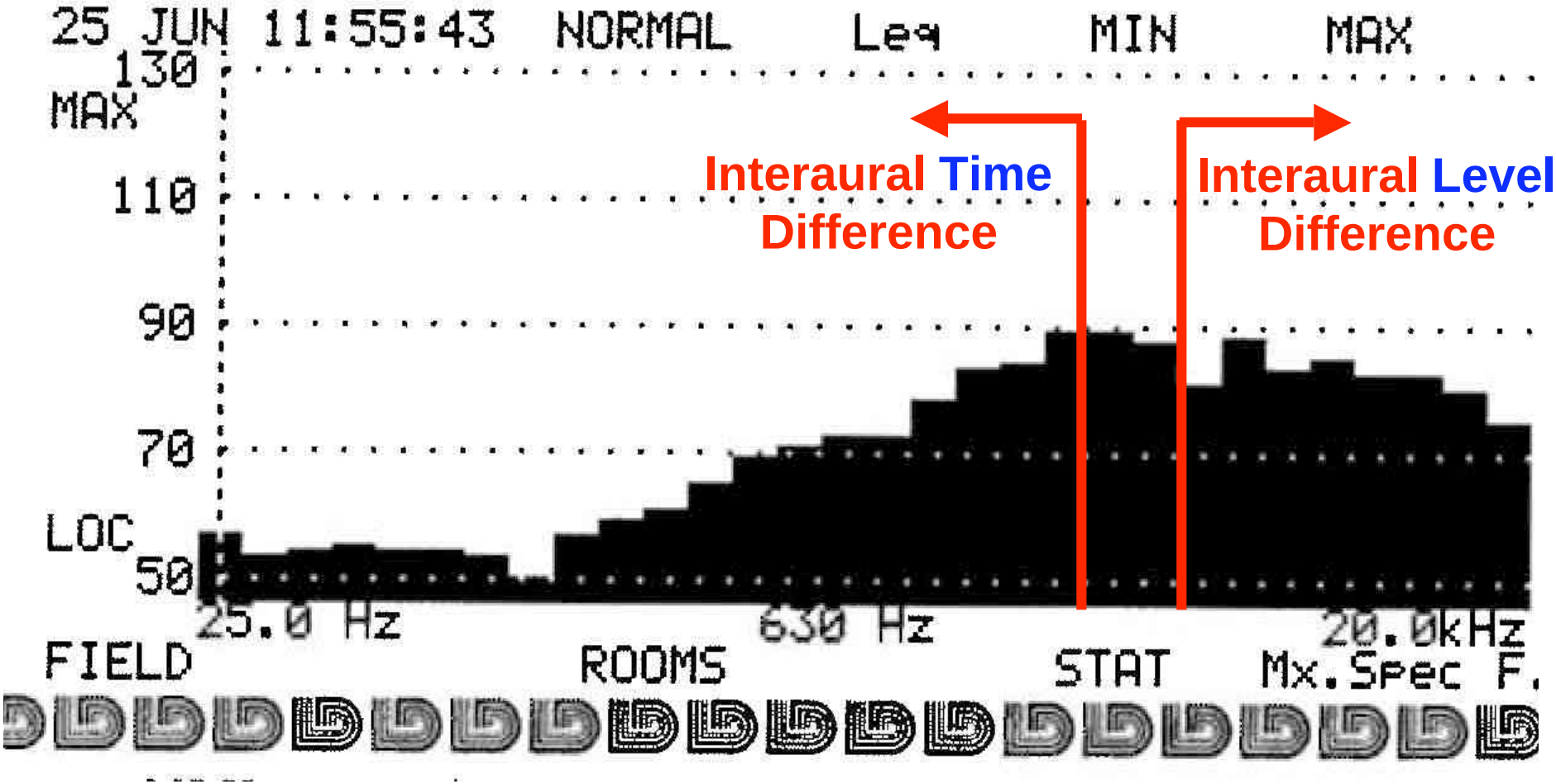
Sound Field Setup around Subject's Position

Hidden Generator (54-59 dBA) for Powering Masking Noise (diesel truck @ 82 dBA)

Target Sign #1, 0-degree position, under Flag

2 of 8 Shooter Positions

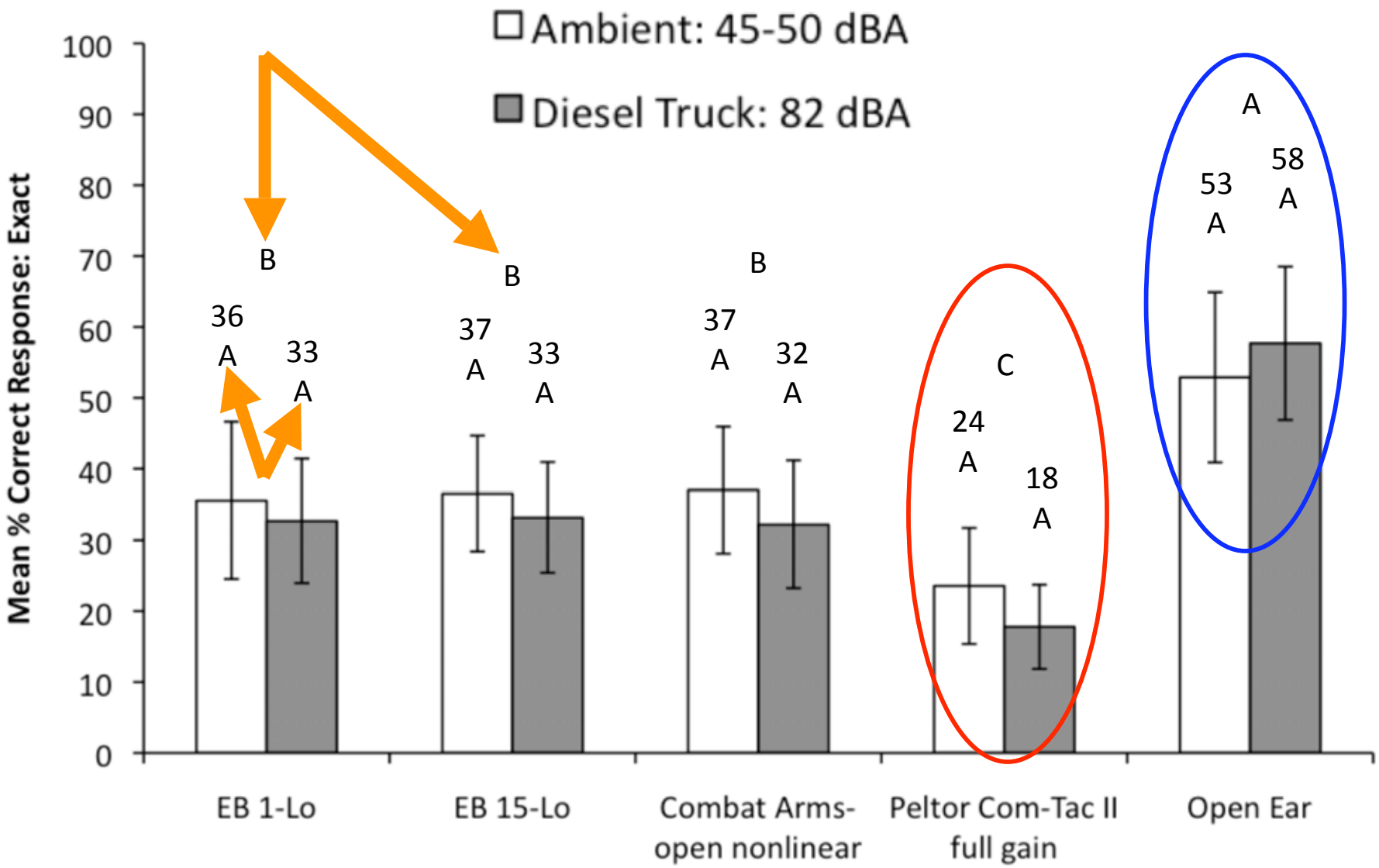
22-cal Blank Gunshot Spectra at Subject's Ear from Shooter's Position @ 150 ft



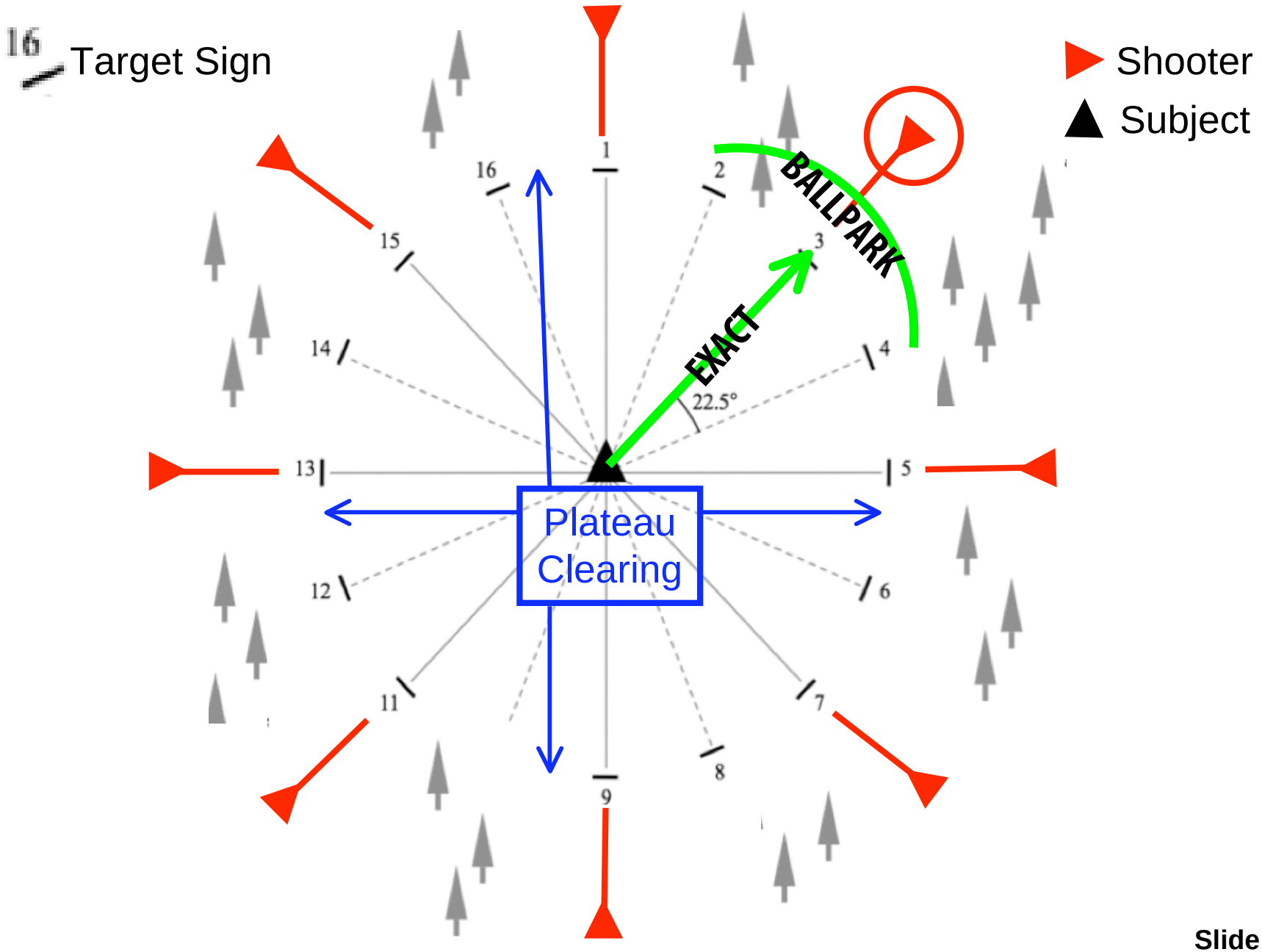
Statistical Analyses on each Dependent Measure

1. ANOVA ($p<0.05$)
2. Breakdown of Main Effects and Interactions
   - Tukey's Test ($p<0.05$)
3. Figures:
   - Means with the same letters are *not* significantly different at $p<0.05$.
   - 95% Confidence Limits shown.

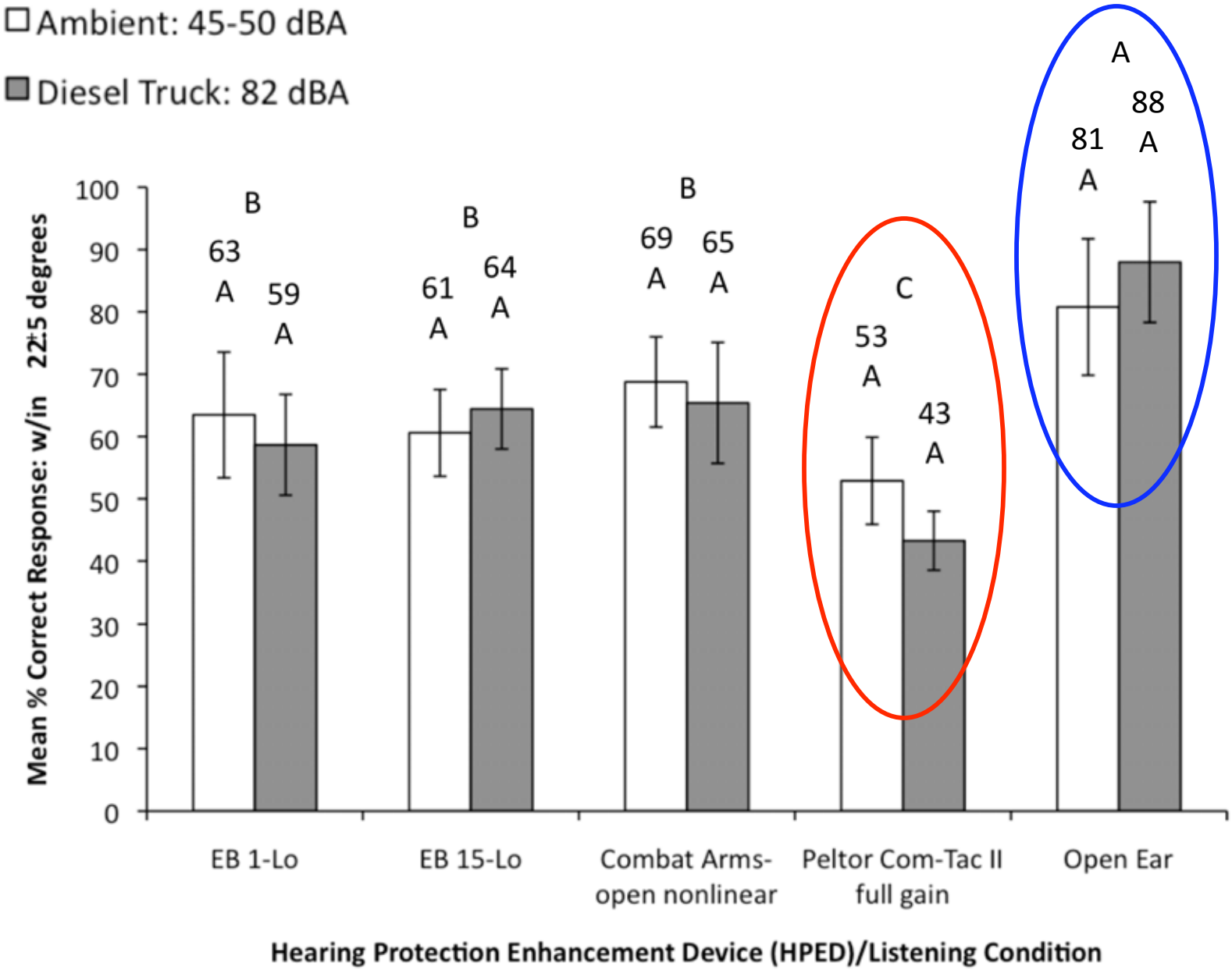
Gunshot Localization
HPED & Noise Effect: % Correct - Exact



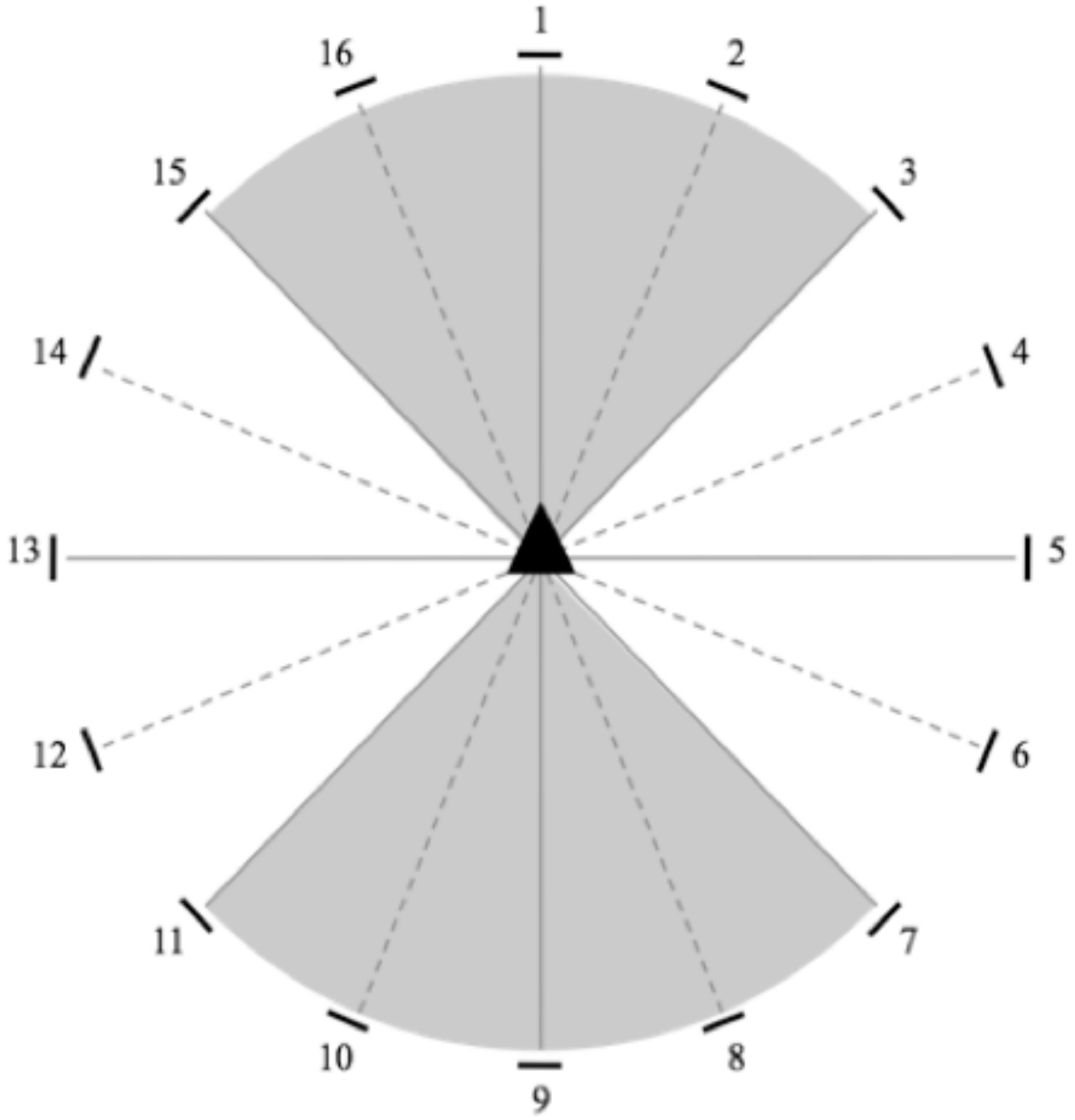
Field Test Site Configuration: *Measures*



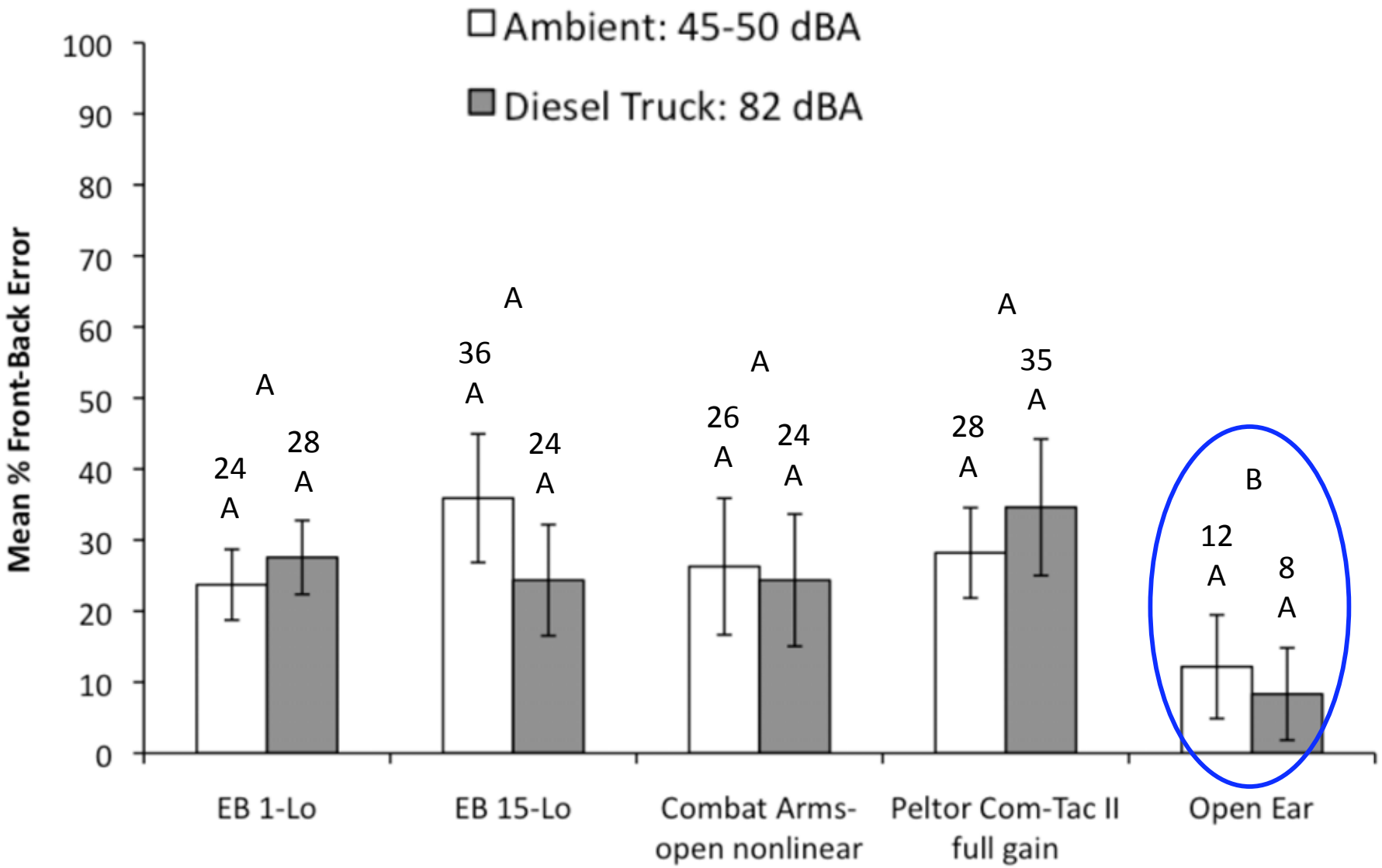
Gunshot Localization
HPED & Noise Effect: % Correct - Ballpark



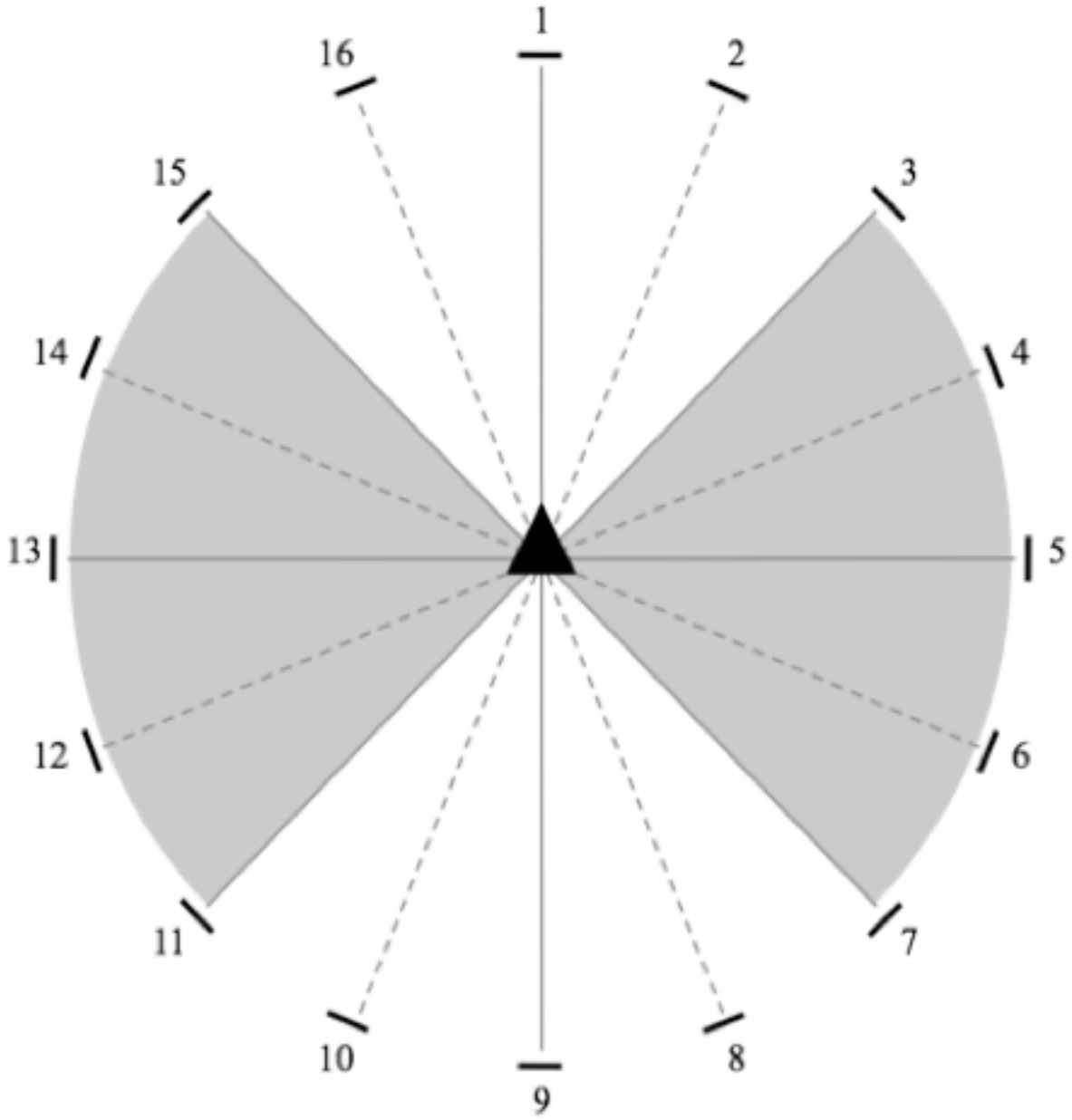
Front-Rear Localization Confusion Regions



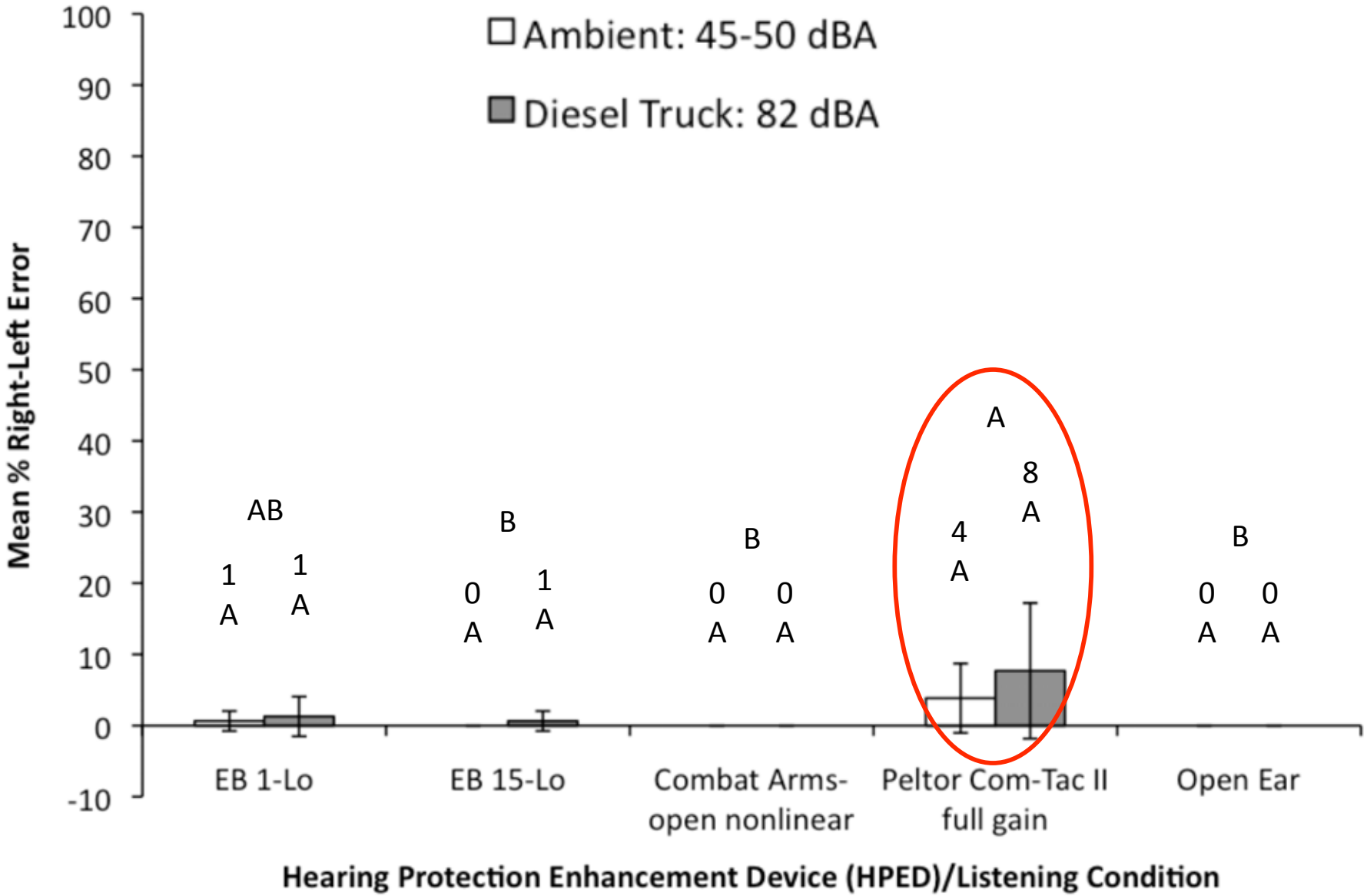
Gunshot Localization
HPED & Noise Effect: % Front-Rear Errors



Right-Left Localization Confusion Regions

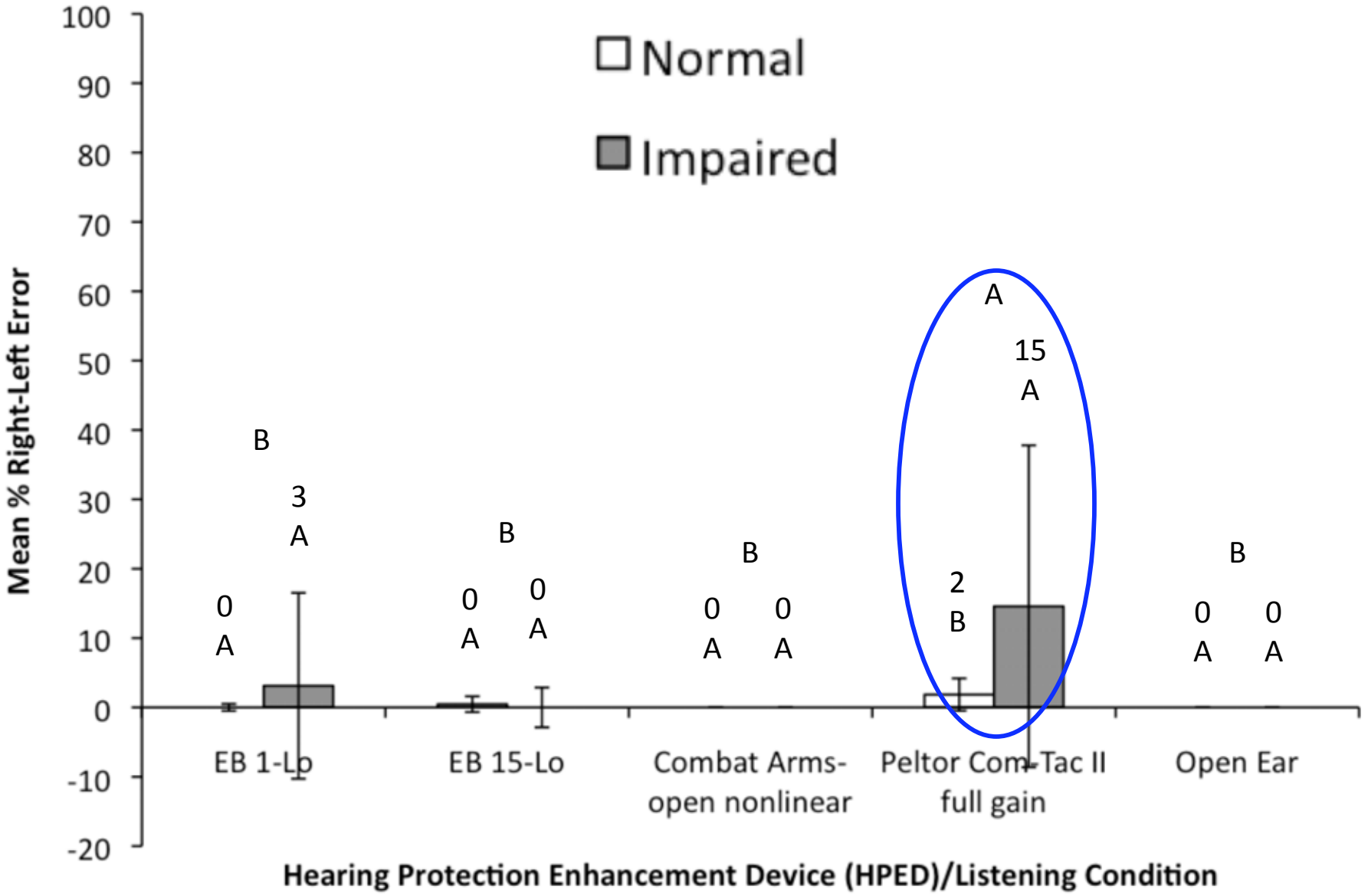


Gunshot Localization
HPED & Noise Effect: % Right-Left Errors

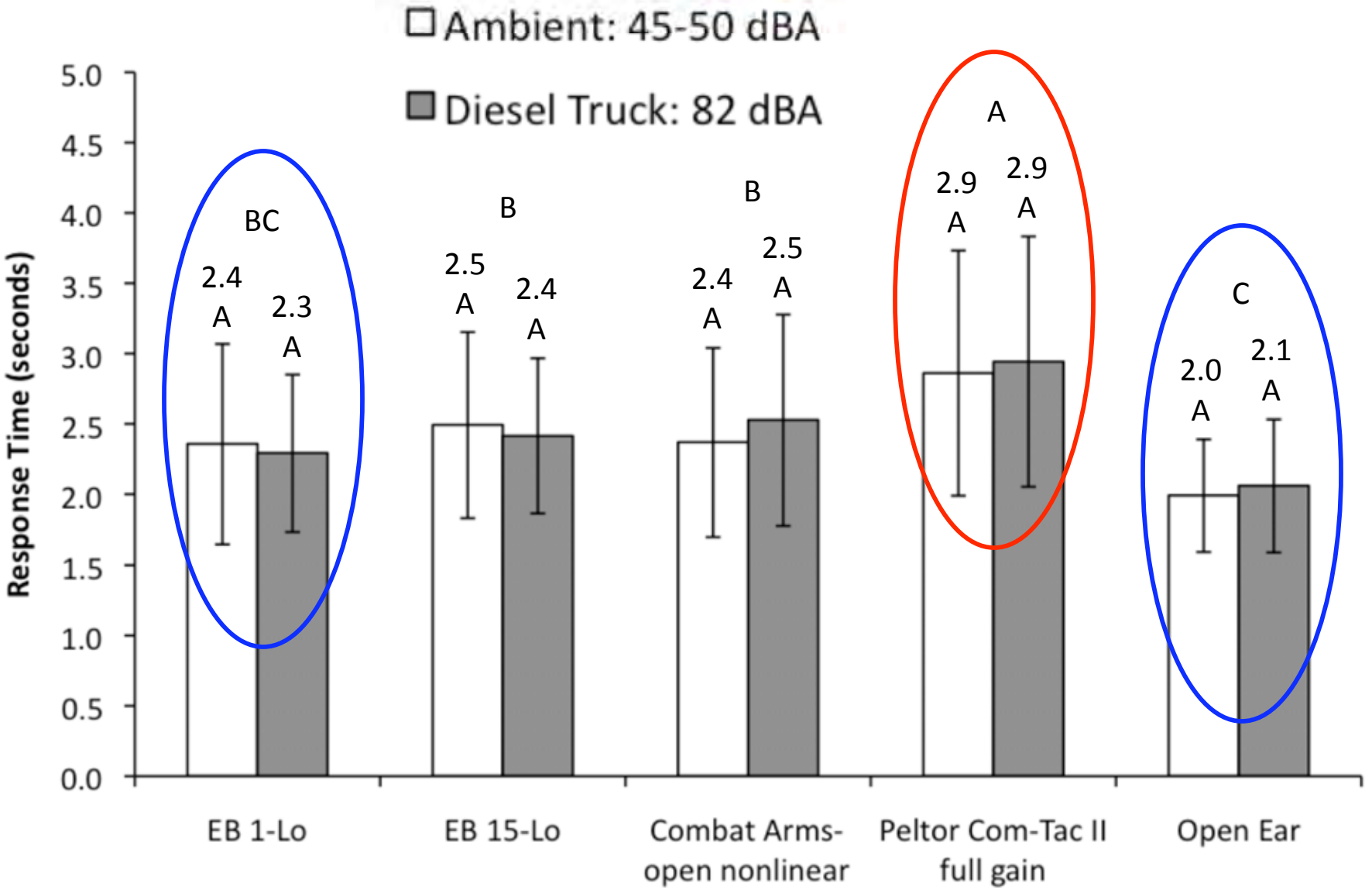


Gunshot Localization

HPED & *Hearing Ability:* % Right-Left Errors

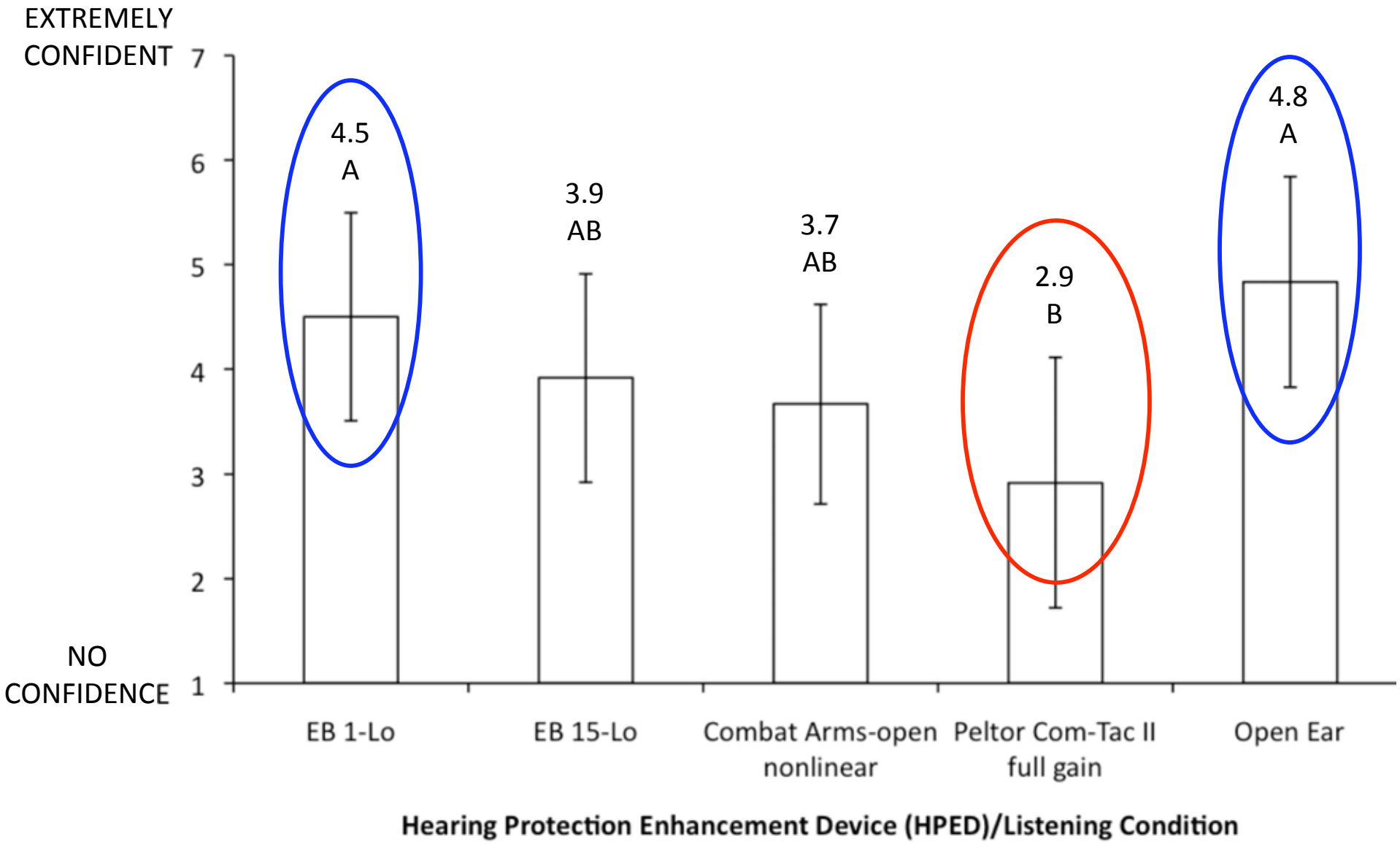


Gunshot Localization
HPED & Noise Effect: Target Response Time

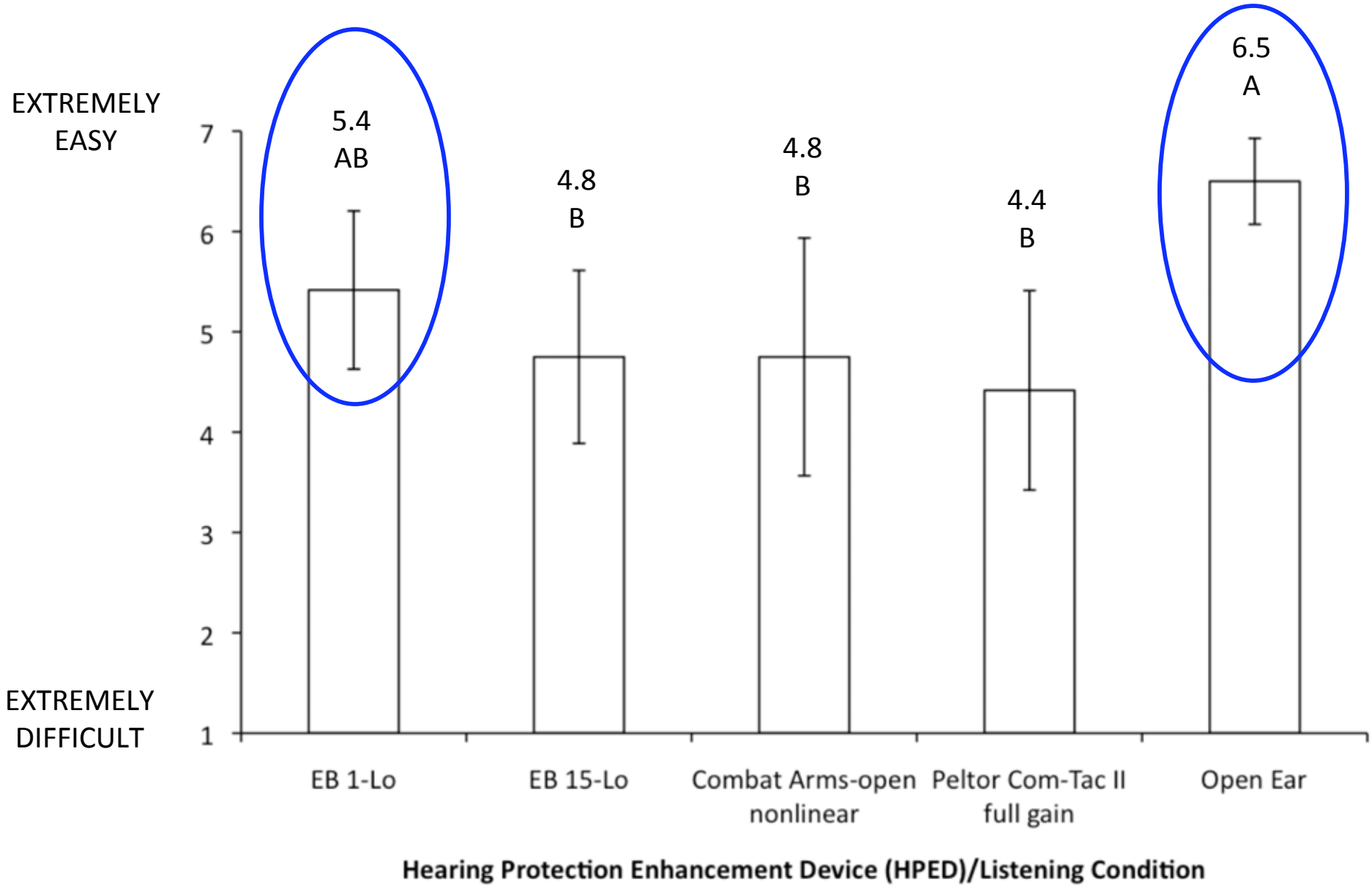


Hearing Protection Enhancement Device (HPED)/Listening Condition

Rating: Confidence in Ability to Locate Gunshots



Rating: How Easy to Communicate with Experimenter



Shooter Position → 1 3 5 7

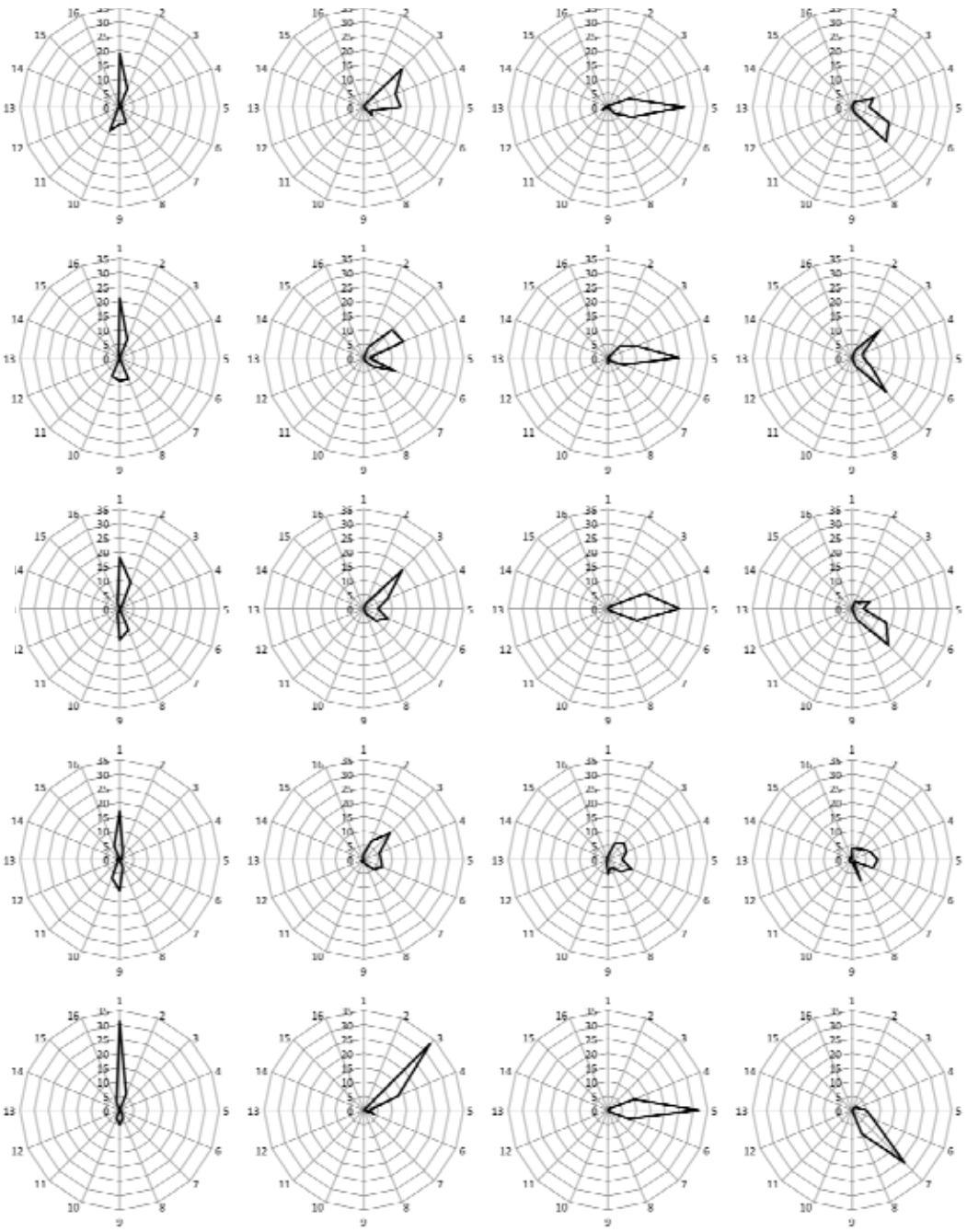
EB 1-Lo

EB 15-Lo

Combat Arms - nonlinear

Peltor Com-Tac II

Open Ear



CONCLUSIONS

?

?

Conclusions: HPED Effects on Localization Accuracy

- On both ‘exact’ and ‘ballpark’ measures, the BlastPLGs were equivalent to the Combat Arms-Open, while the Peltor Com-Tac II was worse, with less than 25% correct exact localization.

- The Open Ear was generally better than than any of the HPEDs on ‘exact’ and ‘ballpark’ measures, but with accuracy only in the 50-60% range for ‘exact’ location.

- For all HPEDs, accuracy to the ‘exact’ location was about half that of accuracy to the ‘ballpark’ location.
  - Evidence that the ear is important for orientation.

Conclusions: HPED Effects on Response Time

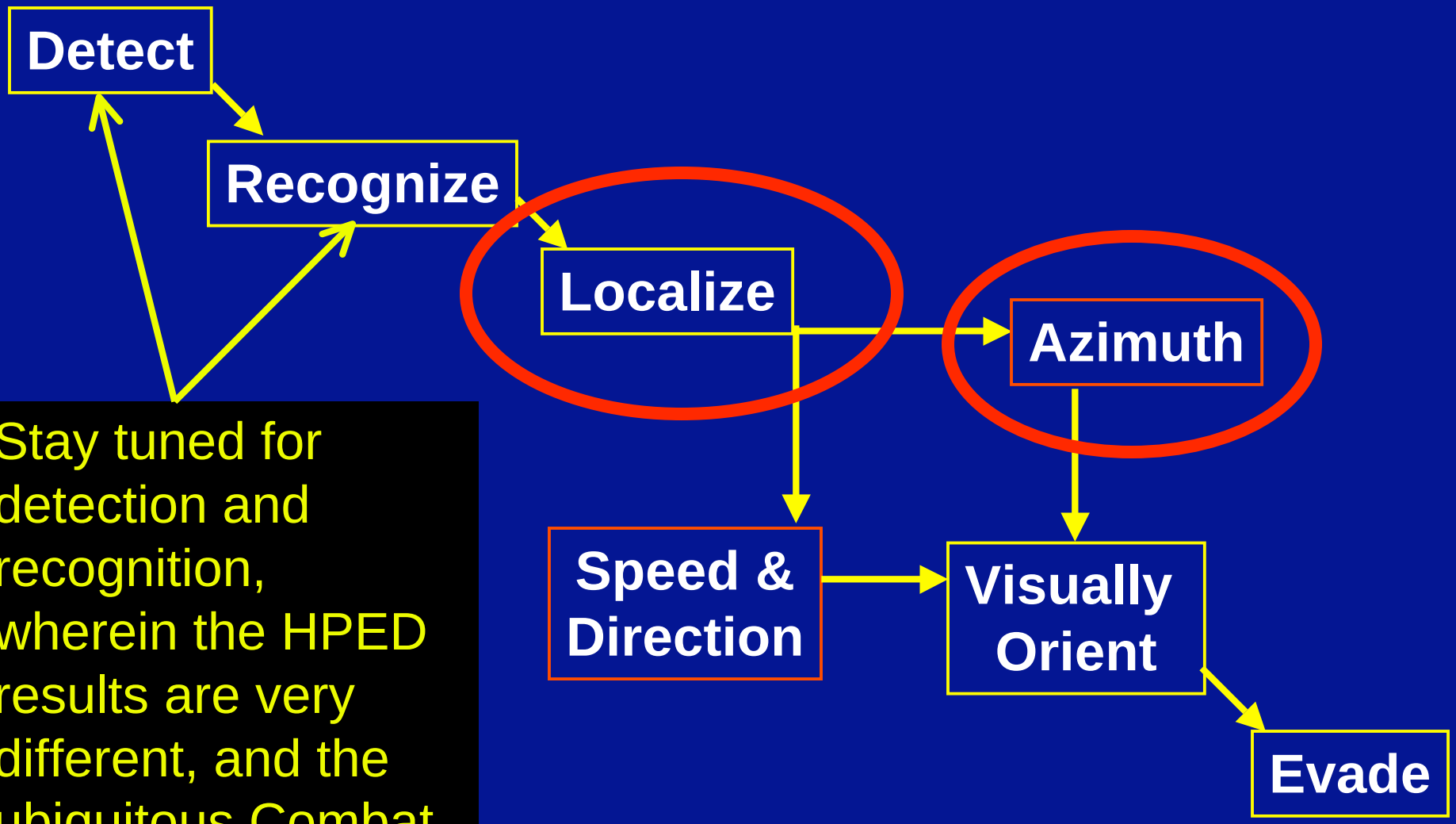
- The Open Ear consistently provided faster response times than any of the HPEDs, except for the BlastPLG EB-1, which was equivalent.

- The Peltor Com-Tac II resulted in longer response times, by about a half-second on average, when compared to the other HPEDs.
  - Subjects were observed to make more "reversals" of head position with the Com-Tac muff.

Final Thoughts

- The choice of HPED makes a substantial difference in auditory localization of gunshots.
- Removing pinnae cues with a muff may not be offset by dichotic design.
- The Open Ear's performance in localization is difficult to improve upon.
- *Critical decisions* about HPED selection to maintain warfighter **auditory situation awareness** must anticipate all major subtask components of that complex task.

Sequential Human Tasks Involving Auditorially-Conveyed Threats



Stay tuned for detection and recognition, wherein the HPED results are very different, and the ubiquitous Combat Arms-Open did not fare as well.

Protect the Warfighter

and maintain aural situational awareness.